Joint Polar Satellite System
Greenhouse Gases & Aerosols

This activity educates students about the various greenhouse gases and aerosols occurring naturally within Earth's atmosphere. The Joint Polar Satellite System (JPSS), a collaborative effort between NOAA and NASA, monitors these greenhouse gases and aerosols in order to provide the Nation with accurate weather forecasts, hurricane warnings, ozone layer health, and much more! Provided is a list of materials that can be purchased to model the different greenhouse gas and aerosol molecules detailed in this activity.

Learning Objectives

Next Generation Science Standards (K-4)

Performance Expectation	*Disciplinary Core Ideas*	*Description*
2-PS1-1 **Matter and Its Interactions**	PS1.A Structure and Properties of Matter	Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties.
2-PS1-4 **Matter and Its Interactions**	PS1.B Chemical Reactions	Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not.
K-ESS2-1 **Earth's Systems**	ESS2.D Weather and Climate	Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.
2-ESS2-3 **Earth's Systems**	ESS2.C The Roles of Water in Earth's Surface Processes	Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form.
3-ESS2-1 **Earth's Systems**	ESS2.D Weather and Climate	Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next.
K-ESS3-2 **Earth and Human Activity**	ESS3.B Natural Hazards	Some kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events.
3-ESS3-1 **Earth and Human Activity**	ESS3.B Natural Hazards	A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (Note: This Disciplinary Core Idea is also addressed by 4-ESS3-2.)

Materials

Greenhouse gas and aerosol molecules can be constructed using any arts and crafts materials. For this classroom/take-home activity, you can use a molecular chemistry set if you have one, but colored construction paper and scissors, crayons, food, or anything else you can think of will also work! This is your chance to use your creativity to construct the JPSS greenhouse gases and aerosols in class or at home!

Vocabulary

Atmosphere: The protective layer of gases surrounding the Earth; the air.

Gas: The state of matter able to expand freely to fill a whole container, having no fixed shape (unlike a solid) and no fixed volume (unlike a liquid).

Ultraviolet: The light (or energy) from the Sun that causes sunburn.

Matter: Any type of material that has mass and takes up space (solid, liquid, or gas form).

Atom: The basic building blocks of matter; microscopic particles.

Molecule: One or more atoms bonded together.

Polar Orbit: An orbit in which a satellite circles the Earth by passing above the North and South Poles.

Water Vapor: Water in gas form.

Air: A mixture of gases in the atmosphere.

Weather: The state of the atmosphere with respect to wind, temperature, cloudiness, moisture, and pressure. Most weather occurs in the troposphere, the lowest layer of the atmosphere.

Greenhouse Gas: Natural gases in the atmosphere that trap the Sun's heat.

Greenhouse Effect: A natural phenomenon occurring in the Earth's atmosphere where the Sun's heat is trapped.

Water Cycle: The natural process through which water moves throughout the Earth's surface, oceans, and atmosphere.

Evaporation: Water changing from liquid to gas, rising from the surface to the atmosphere.

Precipitation: Water falling to Earth's surface as rain, snow, hail, etc.

Condensation: Water changing from a gas to liquid. The process forming clouds.

Landfall: When a hurricane arrives on land.

Ozone: A gas molecule contacting three oxygen atoms.

Ozone Layer: A layer of ozone molecules within the atmosphere absorbing most of the Sun's harmful radiation from reaching the Earth's surface.

Troposphere: The lowest layer of the atmosphere, where most weather occurs.

Exosphere: The outermost layer of the atmosphere, where many satellites orbit Earth.

Lesson

» What is the Atmosphere?

» What Does the Atmosphere Do?

The atmosphere is a protective layer of gases surrounding the entire Earth. This protective layer of gases provides humans with oxygen to breathe, protection from the extreme temperatures of space, protection from the Sun's harmful ultraviolet (UV) radiation, and keeps the Earth habitable. Without the atmosphere, life could not exist on Earth.

If students have trouble grasping the concept, try using the spacesuit analogy.

Question:
How does an astronaut survive in space?

Answer:
A spacesuit, but what does a spacesuit actually do?

- In the vacuum of space, there is no air. A spacesuit provides an astronaut with oxygen to breathe.
- Space can be very cold, or very hot. A spacesuit protects an astronaut from the extreme temperatures in space.
- A spacesuit also blocks the Sun's harmful radiation, mimics Earth's air pressure, and protects astronauts from space particle impacts.

An astronaut's spacesuit duplicates what the atmosphere does for Earth, so a spacesuit is like a mini-atmosphere.

On June 3, 1965, astronaut Edward H. White II became the first American to step outside of a spacecraft, let go, and drift in the zero gravity of space. NASA scientists and engineers had to develop a spacesuit to simulate Earth's atmosphere so astronauts like Edward H. White II could survive in the harsh conditions of space.

Image: www.nasa.gov/multimedia/imagegallery/image_feature_838.html

While the atmosphere is made from tiny microscopic atoms, it can be visible from time to time. This picture was taken by astronauts aboard the International Space Station in 2013. Above the sunrise, the blue and white ripples are actually clouds. Believe it or not, clouds are large collections of liquid water in the atmosphere. When water vapor expands and cools, it condenses into billions of tiny water droplets, and forms a cloud that we can see. The movement of water throughout the atmosphere contributes to the daily and weekly weather cycle. JPSS can measure the water in clouds all day and night.

Image: visibleearth.nasa.gov/images/81887/sunrise-over-the-aleutian-islands-with-noctilucent-clouds

» What is Matter?

» What are Gases?

Matter is any type of material (on Earth or in the universe) that has mass and takes up space — including you.

We cannot see most of the atmosphere because it is made from billions of microscopic particles called atoms. Atoms are the basic “building blocks” of matter.

Atoms can stick (bond) together to form larger molecules, such as water. Water, also known as a “liquid,” is a “state” or “phase” of matter. Matter comes in three common states; solid, liquid, and gas.

The atmosphere is an example of a gas. In fact, the atmosphere is made of many different gases. Scientists study the atoms and molecules that make up Earth’s atmosphere in order to understand why it is unique. To do this, they use Earth observing satellites like the Joint Polar Satellite System (JPSS).

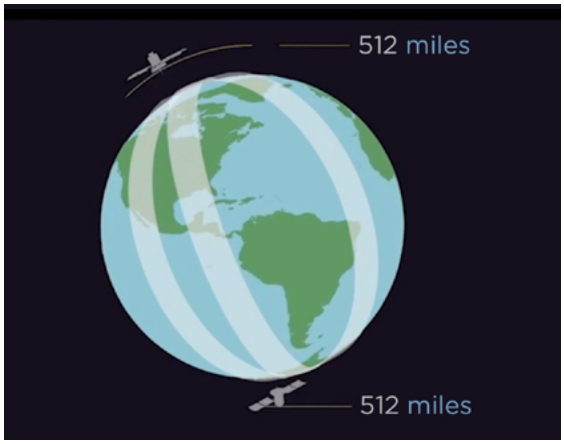
In order to understand the atmosphere, scientists want to know what it is made of.

The atmosphere is made up of a number of different gases including 78% nitrogen, 21% oxygen, with the remaining 1% being other gases such as water vapor, hydrogen and carbon. This mixture of gases makes up the air we breathe.

By understanding what the atmosphere is made of, scientists can study atmospheric events such as cloud formation, daily weather, hurricanes, and even volcanic eruptions.

The Joint Polar Satellite System currently includes two satellites—the Suomi National Polar-orbiting Partnership (Suomi NPP), and NOAA-20, and recently launched in 2022, NOAA-21, depicted above.

Image: www.nesdis.noaa.gov/current-satellite-missions/currently-flying/joint-polar-satellite-system



JPSS in polar orbit. JPSS takes approximately 50 minutes to travel from the North Pole to the South Pole and orbits the entire Earth 14 times a day. To do this, JPSS orbits at approximately 512 miles above Earth’s surface, traveling at approximately 17,000 miles per hour.

Image: www.nesdis.noaa.gov/content/jpss-joint-polar-satellite-system-overview

» What are Greenhouse Gases?

Nitrogen, oxygen, carbon, hydrogen, and other gases in the atmosphere can stick (bond) together to form natural gas molecules, or natural greenhouse gases.

There are five natural greenhouse gases in Earth's atmosphere. These include water vapor, ozone, carbon dioxide, methane, and nitrous oxide.

Greenhouse gases are an important part of the atmosphere because they protect the Earth from the Sun's harmful UV radiation while creating the right temperatures to support life.

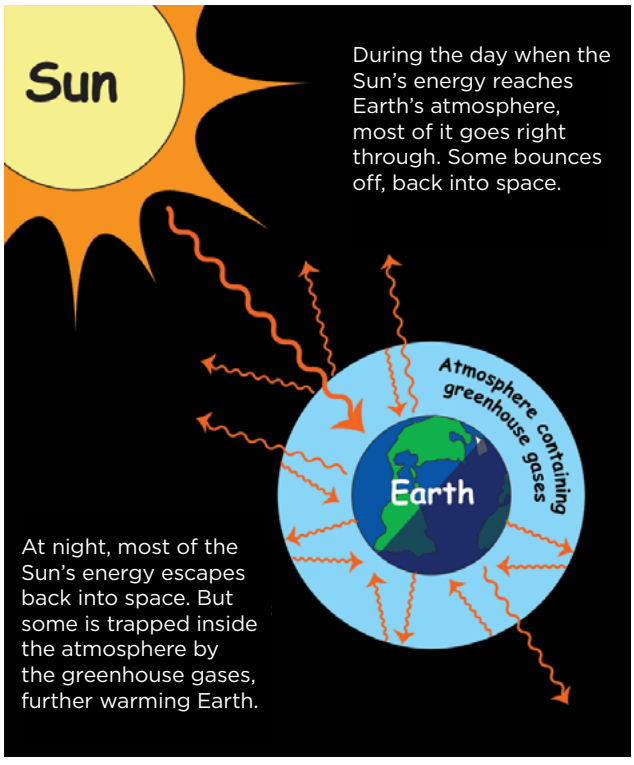
Greenhouse gases allow sunlight to pass through the atmosphere, trapping heat, and warming the Earth.

This is what is called the "greenhouse effect."

A natural greenhouse effect keeps the Earth at a stable temperature, allowing the Earth to stay warm enough for life to exist. Without greenhouse gases, the Earth would be too cold.

JPSS monitors what greenhouse gases are in the atmosphere, where they are located, and how much there are.

For example, scientists are very interested in monitoring water vapor and ozone.



A drawing depicting the Earth's atmosphere full of the 5 natural greenhouse gases and the "greenhouse effect." Without this natural process, the Earth would be too cold for life to exist.

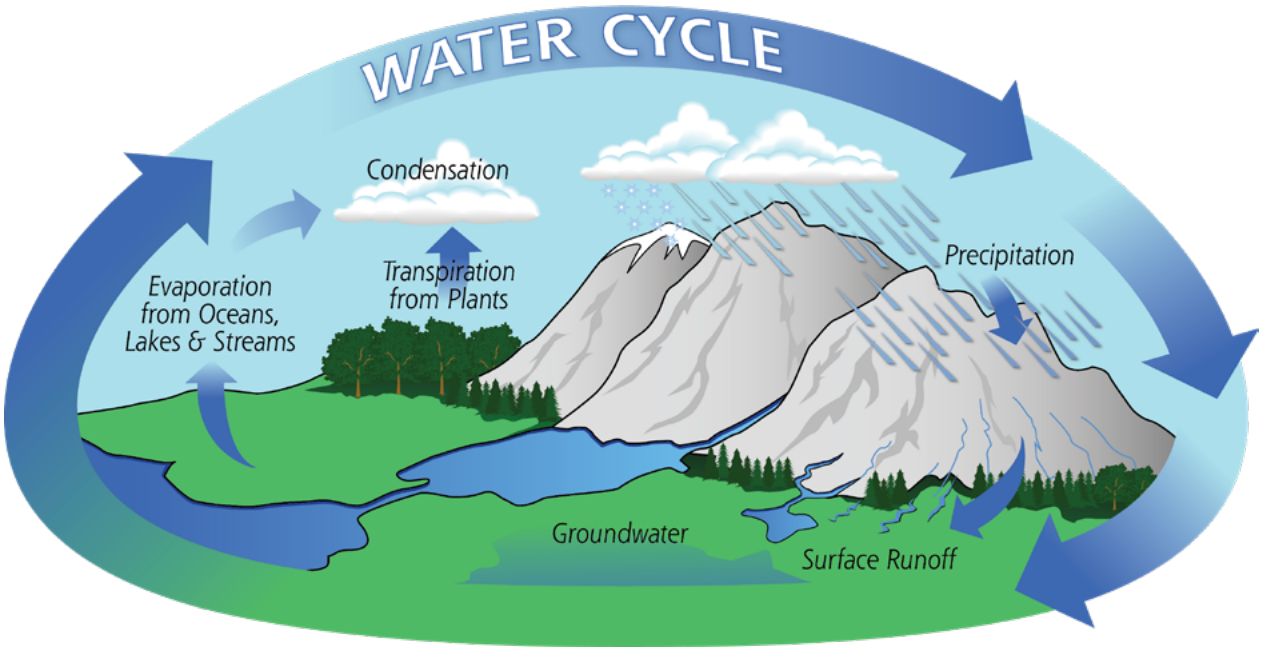
Image: spaceplace.nasa.gov/greenhouse/en/

» Water Vapor and Weather Activity

Approximately 0.001% of the total water on Earth is in the atmosphere as water vapor (water in gas form). This is enough water to cover the entire surface of Earth with 1 inch of rain!

Understanding where and how much water vapor is in the atmosphere helps scientists predict weather, making it a very important greenhouse gas.

For example, water vapor influences cloud formation, atmospheric temperature, and moisture. All of these properties of the atmosphere influence the weather.



The above image shows the Earth's water cycle. The water cycle is the movement of water around Earth's surface, oceans, and atmosphere. Depending on its temperature, water can be a solid, liquid or gas. For example, when liquid water in the ocean gets hot, it evaporates into water vapor (gas) and rises into the atmosphere. When the water vapor in the atmosphere cools, it condenses back into billions of tiny water droplets. We see these large collections of water droplets floating in the air as clouds. The water droplets in a cloud condense into one another and begin to grow. When the water droplets get too heavy they precipitate as rain or snow, and fall back to the surface. If liquid water is exposed to extremely cold temperatures, it turns into solid ice. The water cycle has been going on for billions of years! JPSS monitors all the water vapor in the atmosphere and where it is moving.

Image: pmm.nasa.gov/education/sites/default/files/article_images/Water-Cycle-Art2A.png

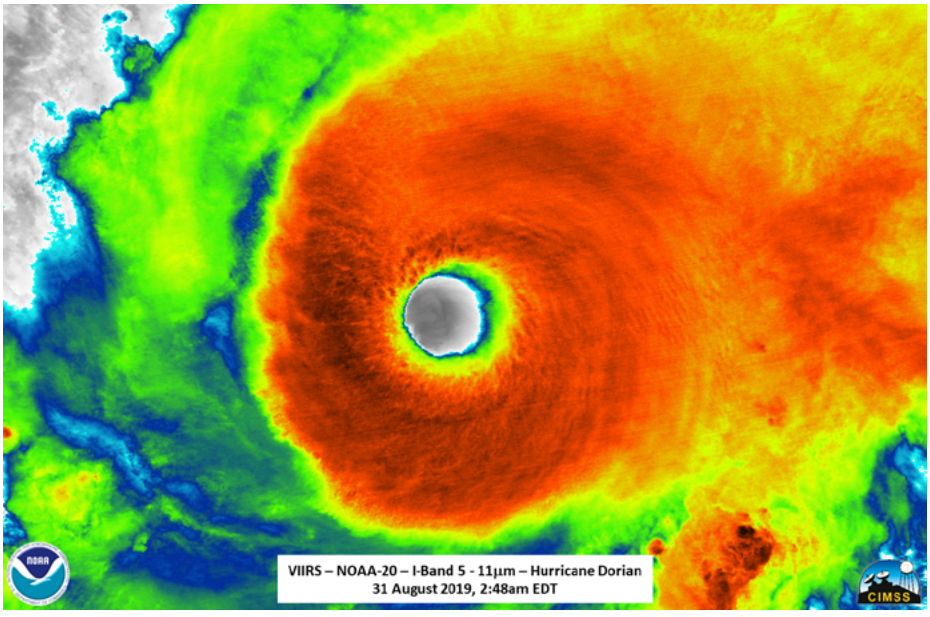
» Advanced Technology Microwave Sounder (ATMS)

Understanding past, present, and future weather patterns is one of the primary missions of JPSS. In order to understand and predict the weather, scientists must understand the movement of water throughout the atmosphere.

The Advanced Technology Microwave Sounder (ATMS) is a scientific instrument aboard JPSS that monitors water on the Earth's surface, oceans, and atmosphere all day and night. This includes the water in solid, liquid, and gas form (rain, snow, ice, vapor, etc.). However, ATMS mostly monitors the water vapor in the atmosphere.

Why is monitoring water important?

Scientists need to make sure water is distributed around the Earth properly. Understanding the amount and location of water vapor in the atmosphere allows scientists to accurately predict state and local weather conditions 3 to 5 days in advance. More importantly, the data gathered from ATMS can inform scientists when there will be severe weather, such as thunderstorms and hurricanes.



Hurricane Dorian was the first major hurricane of the 2019 Atlantic hurricane season. Dorian became a Category 4 hurricane on August 31st and a Category 5 on September 1st. That day, the JPSS Visible Infrared Imaging Radiometer Suite (VIIRS) took this picture. JPSS was able to track Dorian before it was a hurricane by monitoring the warm ocean water and water vapor in the atmosphere above the Atlantic Ocean. By understanding where a lot of water vapor is in the atmosphere, scientists can predict where and when hurricanes such as Dorian will form. In addition, they can predict the hurricane's path and where it will make "landfall." When JPSS finds a hurricane, it can help inform people if they are in danger so they can find shelter.

Image: www.nesdis.noaa.gov/sites/default/files/I05_N20_083119_0648_Dorian_eye_nolabels.png

» The Ozone Layer

Ozone is a greenhouse gas located all around the atmosphere, but is mostly concentrated 10 to 20 miles above the Earth's surface. This part of the atmosphere is called the "ozone layer."

The ozone layer is a protective layer of ozone gas surrounding the entire Earth. This greenhouse gas protects life on Earth by absorbing almost all of the Sun's harmful UV light before it reaches the surface.

Without the ozone layer, light from the Sun would harm life on Earth. For example, ozone protects beach goers in the summer from getting sunburnt.

» Ozone Mapping and Profiler Suite (OMPS)

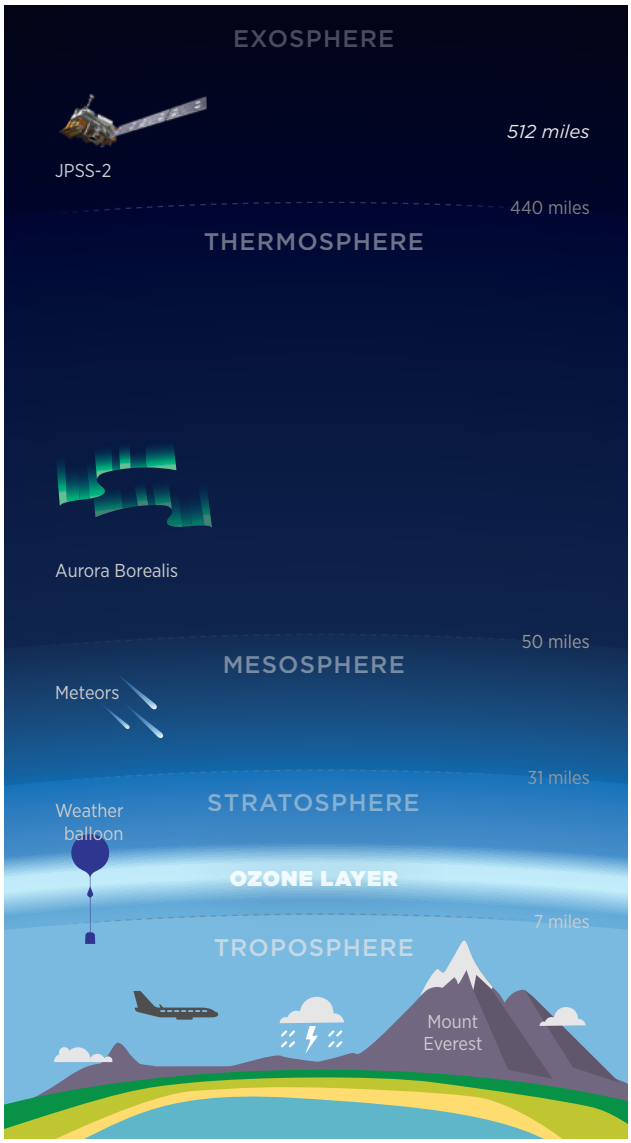
The ozone layer is a very important part of the Earth's atmosphere and scientists want to make sure it stays healthy by using Earth observing satellites like JPSS to monitor ozone molecules.

How? The Ozone Mapping and Profiler Suite (OMPS) is another scientific instrument aboard JPSS that monitors the amount of ozone molecules around Earth's atmosphere. OMPS can measure the ozone molecules all around the Earth from the surface to approximately 30 miles high!

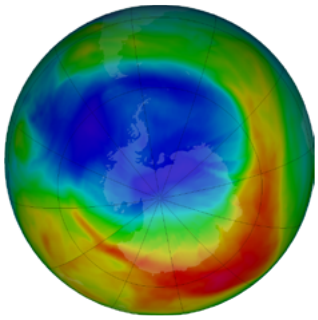
By using the OMPS instrument and a polar orbit, JPSS can "map" the ozone layer and make sure it stays healthy so it can continue protecting the Earth.

OMPS also provides beach goers with the UV index, telling how much of the Sun's UV light is passing through the atmosphere. This number can tell you how much sunscreen to put on, protecting you from sunburn.

The Earth's atmosphere also contains natural aerosols. Read below to learn more and construct all the different greenhouse gases and aerosols the Joint Polar Satellite System monitors every day.



The above picture shows the different layers of Earth's atmosphere. The lowest level, the troposphere, is where all of Earth's weather activity happens and contains 99% of the atmosphere's water vapor. Just above the troposphere is the ozone layer. The ozone layer is approximately 10-20 miles above the Earth's surface, but this number can vary based on location and season. JPSS orbits within the outermost layer of Earth's atmosphere, the exosphere. Scheduled to launch in 2022, JPSS-2 will also orbit within the exosphere at 512 miles above Earth's surface.

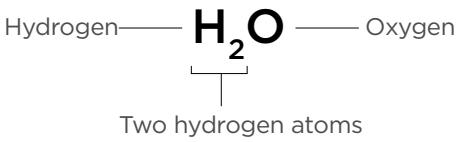


Color-enhanced view of total ozone over the Antarctic taken on September 8, 2019. The purple and blue colors are where there is the least ozone, and the yellows and reds are where there is more ozone. By using a polar orbit, JPSS can monitor and "map" the amount of ozone molecules all around the Earth and each pole. Scientists have been monitoring and tracking the health of the ozone layer for 30 years.

Image: ozonewatch.gsfc.nasa.gov/Scripts/big_image.php?date=2019-09-08&hem=S

Instructions

Each greenhouse gas and aerosol has a molecular formula. This formula is like a "recipe," telling you what atoms, or ingredients the molecule is made of. Try and construct all 5 greenhouse gases and all 3 aerosols. See the Water Vapor formula below.



Molecular Model Guide

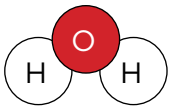
Formula	Gas Molecule
H_2O	Water Vapor
O_3	Ozone
CO_2	Carbon Dioxide
N_2O	Nitrous Oxide
CH_4	Methane
NaCl	Sea Salt
SO_2	Sulfur Dioxide
H_2SO_4	Sulfuric Acid

Atom	Element	Color
H	Hydrogen	White
C	Carbon	
N	Nitrogen	
O	Oxygen	
Na	Sodium	
Cl	Chlorine	
S	Sulfur	

Greenhouse Gases

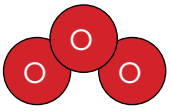
Greenhouse gases are an important part of Earth's atmosphere. They allow sunlight to pass through the atmosphere, trapping heat, and creating stable temperatures to support life on Earth. This is what is called the "greenhouse effect." Without greenhouse gases, the Earth would be too cold. JPSS monitors the 5 natural greenhouse gases found in Earth's atmosphere.

Water Vapor **H_2O**



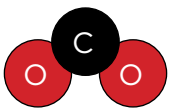
There is enough water vapor (water in gas form) in the atmosphere to cover the entire surface of Earth with 1 inch of rain! JPSS monitors where and how much water vapor is in the atmosphere, helping scientists predict weather and hurricane formation.

Ozone **O_3**

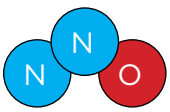


Ozone is mostly concentrated 10 to 20 miles above the Earth's surface. The "ozone layer" surrounds the Earth, protecting life from the Sun's harmful ultraviolet rays (the rays that cause sunburn). JPSS monitors the ozone to make sure it stays healthy.

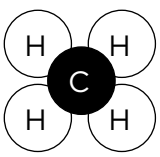
Carbon Dioxide **CO_2**



Nitrous Oxide **N_2O**



Methane **CH_4**



Carbon Dioxide, Nitrous Oxide, and Methane are 3 of the 5 natural greenhouse gases. All 5 greenhouse gases protect Earth from the Sun's harmful ultraviolet light while creating the right temperatures to support life.

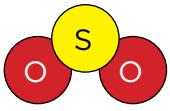
Aerosols

Aerosols are tiny, solid particles and liquid droplets in the atmosphere. Large amounts of natural aerosols are released into the atmosphere as sea salt, desert dust, smoke and volcanic ash. JPSS monitors aerosols in order to understand their effect on the atmosphere.

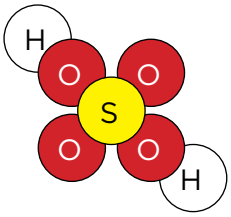
Sea Salt **NaCl**

Sea salt and desert dust are flung into the atmosphere by high winds. JPSS can monitor large amounts of aerosols in the atmosphere as they scatter sunlight, affecting the size of clouds.

Sulfur Dioxide **SO_2**



Sulfuric Acid **H_2SO_4**



Sulfur Dioxide and Sulfuric Acid are released into Earth's atmosphere after a volcanic eruption. Volcanic ash can block an airplane pilot's vision when flying. JPSS monitors volcanic eruptions in order to safely guide airplane pilots through the atmosphere.